Mini Project Lab Report

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Abstract

When designing a motor, depending on the functionality and purpose, allowing the motor to spin in both directions is imperative in most technological cases. The objective we faced was being able to use a Basys 3 Board and a designed H-Bridge to spin a DC motor in both directions, clockwise and counterclockwise, with variable speed control using Pulse Width Modulation (PWM). The overall program and hardware implemented portion was a success, however, indicating the overcurrent warning on the seven segment display was not established.

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1. Introduction

While planning the project, developing a general flow chart helped in order to better develop and analyze methods to successfully meet the objective while also being efficient. A general flowchart [Figure 1] can be structured in order to visualize the process and configuration of the project.

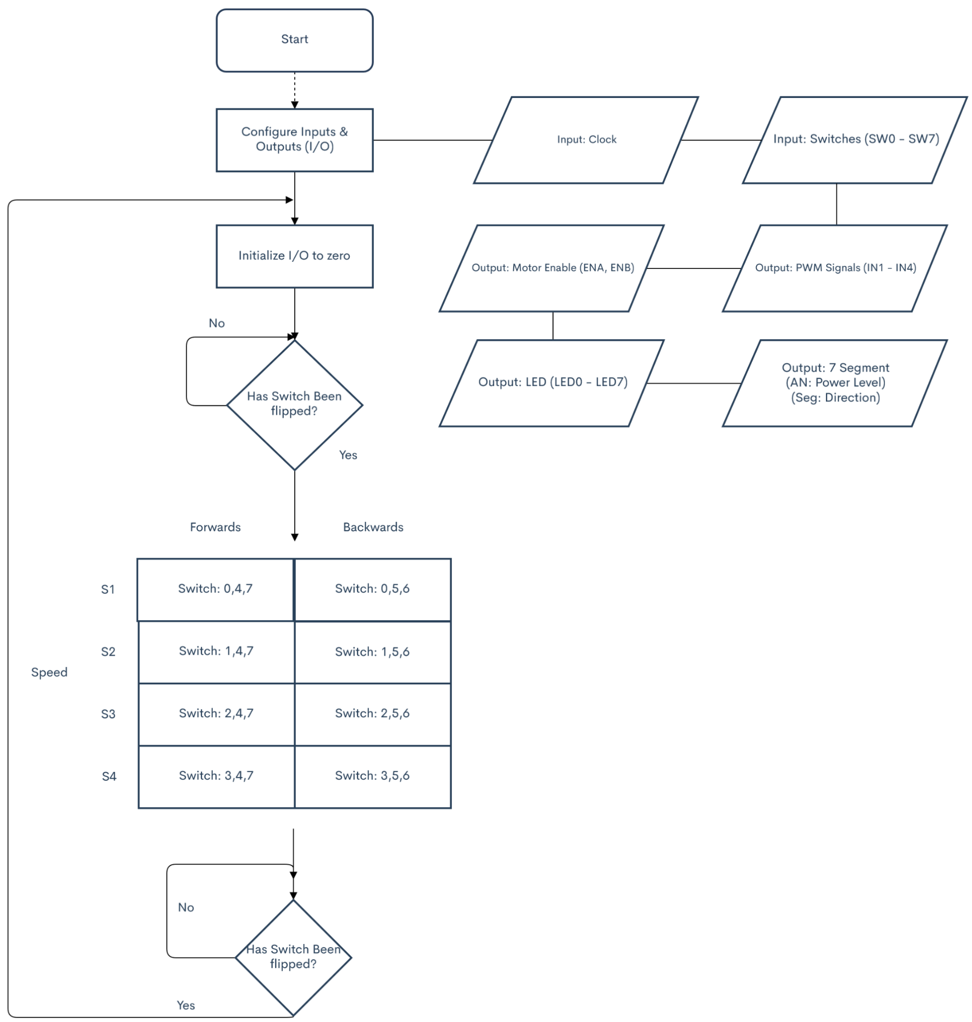


Figure 1: Mini Project General Flowchart

The overall statement was to maintain under 1 ampere using software and hardware implementation. Before the while statement, the inputs and outputs have to be configured in order to determine different elements such as the LEDs, switches, etc.. While this statement is true the program and hardware has to wait for an input from the user, in this case switch zero to switch seven (SW0 - SW7) which is located on the basys board itself. Depending on the switches utilized, the motors are controlled in different ways.

2. Components

Multiple components were used in order to achieve the objective. Specifically, the voltage regulator, comparator, basys board and h-bridge. The Basys board has a limit for the maximum voltage of 5.5 volts direct current (DC) The voltage regulator (LM340T5) [Figure 2] was used in order to connect the voltage source of the 9.6 Volt battery to the basys board.

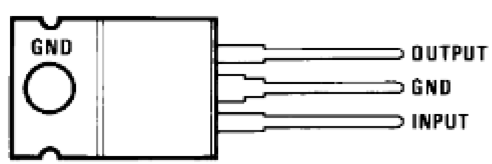


Figure 2: LM340T5 Voltage Regulator

The regulator takes the input and uses a closed feedback loop in order to maintain a constant voltage for the output. The output is then directed to the basys board to provide a constant 5 Volts. Using a voltage regulator in order to connect the battery power supply to the basys board proved to be efficient and cost effective. In order to provide power for the motor and change the direction of current flow, an H-Bridge is required (L298) [Figure 3]. This component allows the change of current flow by utilizing transistors and depending on the flow, the motor will spin clockwise or counterclockwise.

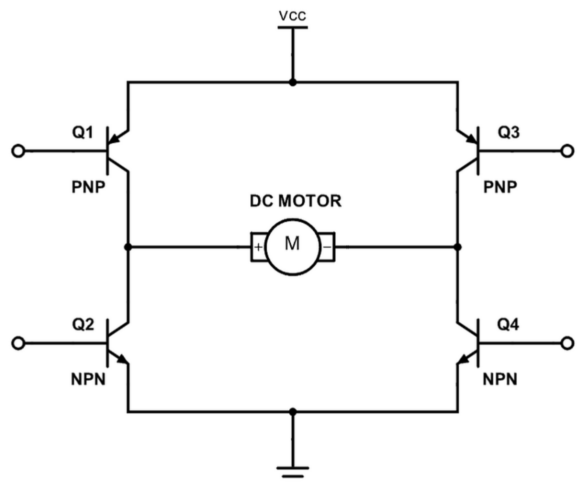


Figure 3: L298 H-Bridge

Another important component utilized in the project is the comparator (LM399) [Figure 4]. The comparator is used in order to implement the software overcurrent protection.

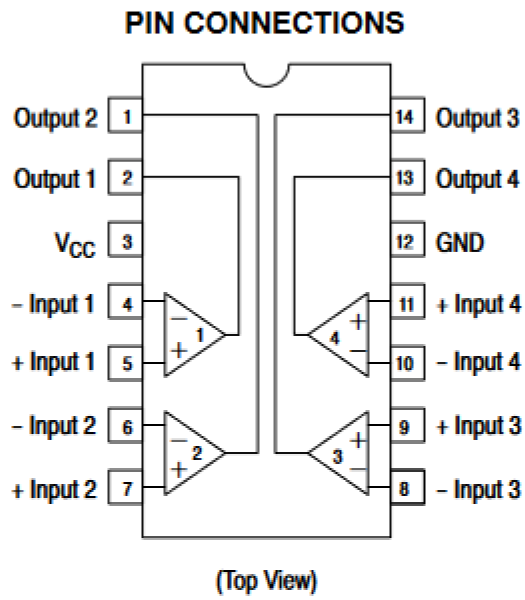


Figure 4: LM339 Quad-Comparator

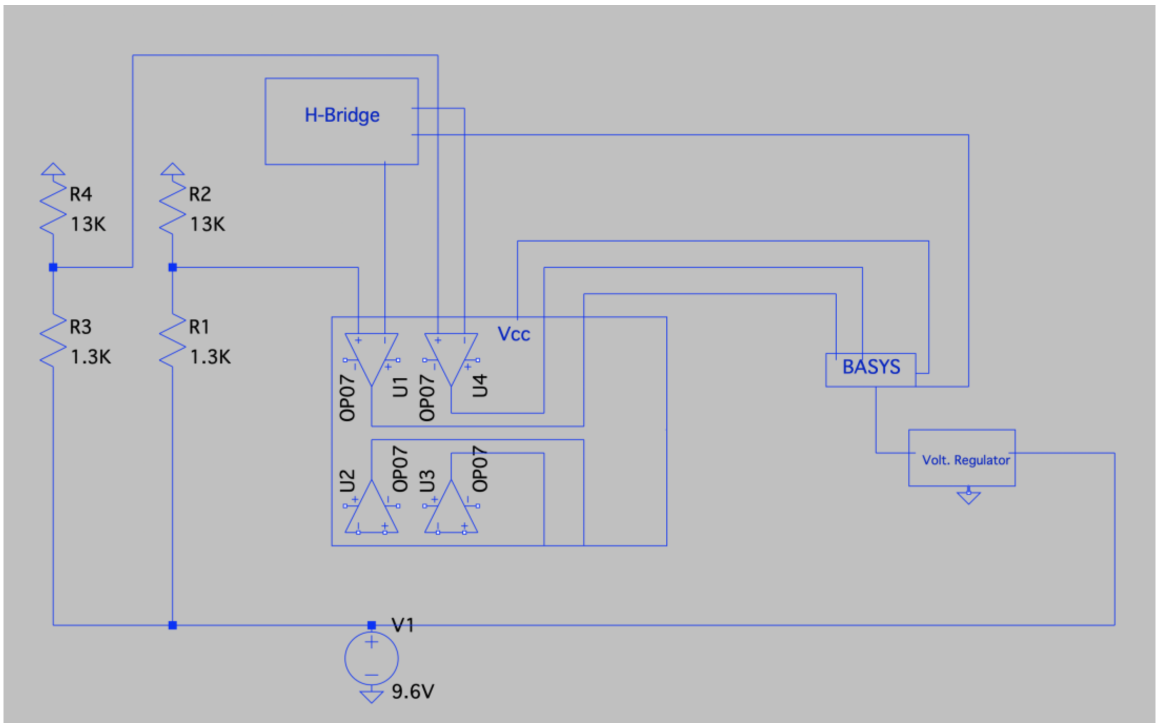
The specific comparator used contained four different mini comparators within the component. However, only two were required in order to compare the sensor from motor A and sensor from motor B. These sensors send a voltage to their corresponding comparator which is compared to 1 volt coming from the non- inverted portion. The calculation of the values needed can be acquired using Ohm's law equation:

$$V = R * I \tag{1}$$

Where *V* is represented as voltage (volts), *R* is represented as resistance(ohms), and *I* represents the current (amps). Since the input provided to the comparator as the reference is needed to be one volt, using ohm's law, it is determined that a resistance factor of one ohm is needed to achieve the current factor of one amp. If the sensor outputs more than one volt, then ideally the comparator should send the signal to ground. Otherwise, the comparator constantly monitors the voltage flow until a greater voltage is inputted.

3. Hardware Setup

After defining and understanding the components involved within the project, the components can be combined and connected to each other in order to finalize the hardware portion of the project. A circuit diagram [Figure 5] can be constructed in order to better understand how each component works together.



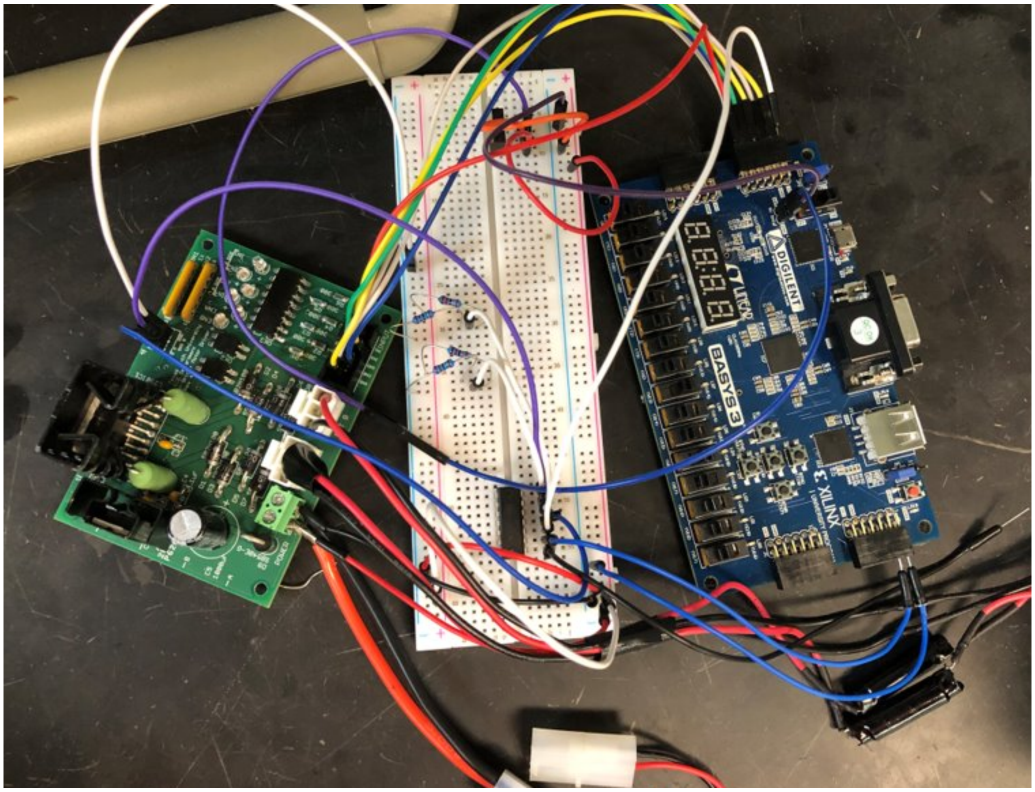


Figure 5: Hardware Circuit Diagram and Setup

Specifically, the schematic utilizes the Basys board, H-bridge, voltage regulator and divider, comparator, and the power supply. A component that was not discussed previously was the voltage divider. The divider is used in order to divide the voltage from the 9.6 volt (DC) battery supply using the connection between two calculated resistors. Before addressing the equation for the voltage divider, an important piece of information regarding the battery is required. The battery charges at different rates and outputs different voltages which can be higher than the 9.6 volts specified on the supply. The measured voltage using a multimeter resulted in around 10.1 volts. Due to the higher voltage, the supply has to be taken into effect with the voltage divider The specific equation for the voltage divider is:

$$V_{out} = \frac{V_S * R_2}{(R_1 + R_2)} \tag{2}$$

V_out is the desired voltage output that is needed from the divider. V_s is the voltage supply/ source. In the case of the mini project this is a DC supply. R_1 is the first resistor. R_2 is the second resistor [Figure 6]. The calculated values for the resistors, with the voltage supply set to 10.1 volts and the output voltage roughly 1 volt, requires resistor one to be 13k ohm and resistor two to be 1.3k ohm. After determining calculations by hand LTspice, a circuit builder and simulator, confirmed the calculations to be around 918 millivolts. (=~ .918 volts)

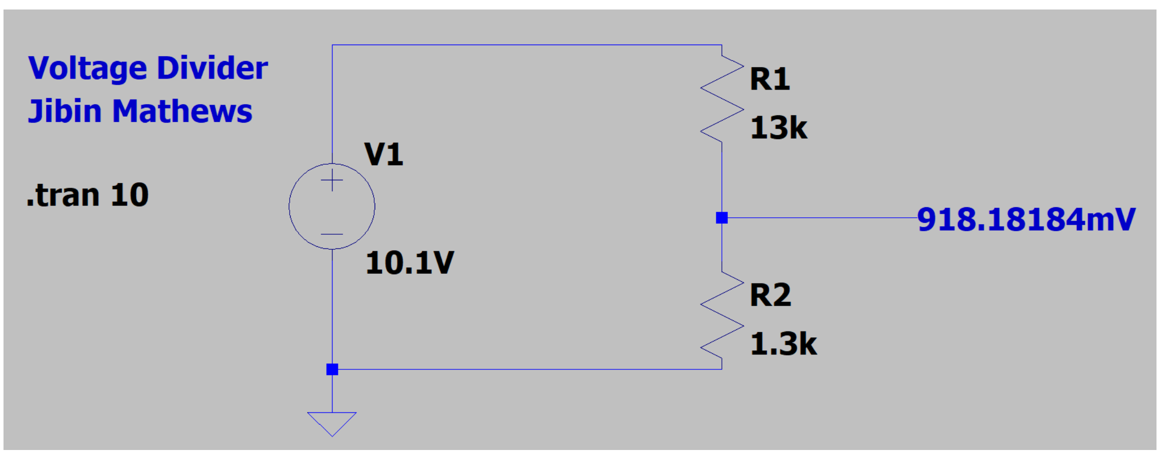


Figure 6: Voltage Divider

4. Software Flowchart

Using Figure one, the development of the code can be simplified into different portions. In the case of the project, the segments can be divided into multiple portions.

Addressing the configurations of Inputs and Outputs (I/O) using switches and LEDs are an important segment to the code. Using the provided .xdc file provided by Diligent, the constraints were simple to assign different ports since they only needed to be assigned within the file. After configuring the inputs and outputs, the I/O is then initialized to zero in order to assign a beginning value to indicate no movement from the motor. The code then waits for user input. This is visualized as a switch being flipped, in the case of the specific project, certain switch assignments according to the truth table [Figure 7].

Switches	0	1	2	3	4	5
25% Speed Forward	1	0	0	0	1	0
50% Speed Forward	0	1	0	0	1	0
75% Speed Forward	0	0	1	0	1	0
85% Speed Forward	0	0	0	1	1	0
25% Speed Backward	1	0	0	0	0	1
50% Speed Backward	0	1	0	0	0	1
75% Speed Backward	0	0	1	0	0	1
85% Speed Backward	0	0	0	1	0	1

Figure 7: Truth Table for Rover Speed and Direction

After the specific switch has been flipped, the program's function is to wait until either the switch is flipped to zero or until another switch is flipped. The table shows that the direction depends on switches four and seven, which represents the forward movement of both A and B motors. While switches five and six represent the backwards movement of both motors. Switches zero through three represent the different speeds. These different speeds are achieved using Pulse Width Modulation (PWM). [Figure 8]

```
//      Duty cycle use in PWM:
    reg [20:0] count;// 2^(21) = 2,097,152
    reg [20:0] width;
    reg PWM;

//      Initialize values to zero
    initial begin
        count = 0;
        width = 0;
        PWM = 0;
     end

always@(posedge clock)begin
        if(count > 2097152) //resets the counter to 0 or increments
            count <= 0;
         else
            count <= count +1;

        if(count < width) begin
            PWM <= 1;
            end

        else begin
            PWM <=0;
         end
end

//      Period(Width): (2^(21)) * (Duty Cycle % / 100)
```

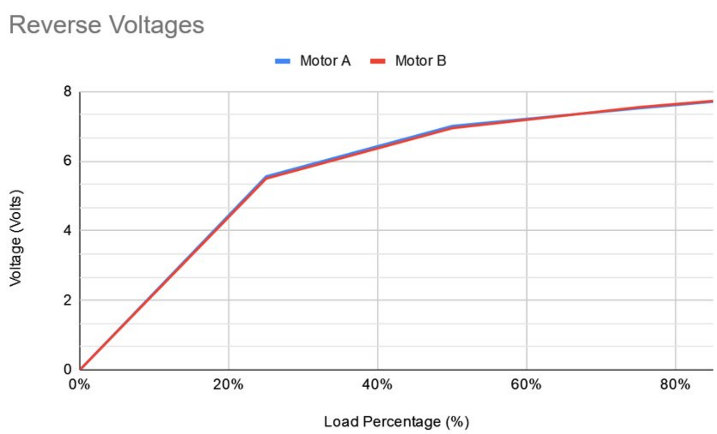
Figure 8: Verilog Coding: Pulse Width Modulation

Using the PWM, the duty cycle can be assigned in order to find the clock value needed in order to power the motor at different load percentages. The equation used to find the period of the width is:

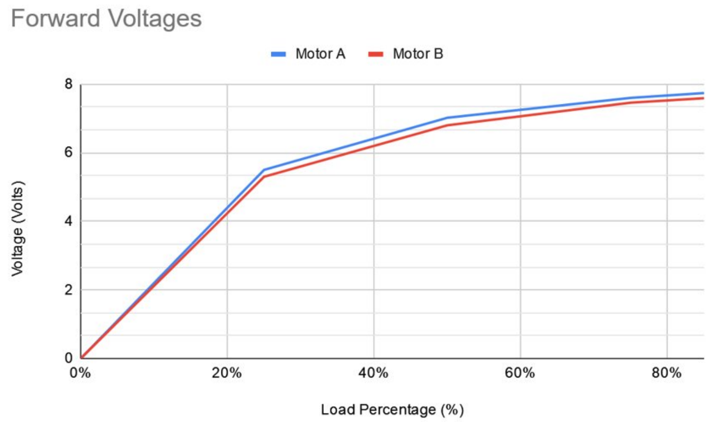
$$(2^{21}) \; * \; (Duty\ Cycle\,\%\,/\,100)$$

(3)

Using this equation, the different clock values for each speed level can be calculated in order to assign the values to the corresponding speed. In order to find the correlation between the duty cycle and the voltage, a multimeter was used in order to graph the correlation. [Figure 9]



Load Percentage (%)	Motor A Voltage (V)	Motor B Voltage (V)
0%	0	0
25%	5.56	5.5
50%	7.01	6.95
75%	7.52	7.55
85%	7.71	7.73



Load Percentage (%)	Motor A Voltage (V)	Motor B Voltage (V)
0%	0 V	0 V
25%	5.5 V	5.3 V
50%	7.02 V	6.8 V
75%	7.6 V	7.46 V
85%	7.74 V	7.59 V

Figure 9: Reverse and Forward Voltages relation to Load Percentage (%)

5. Conclusion

The mini project required different components and the understanding of each piece in order to assemble them together. The hardware component plays an important role in the software and vice versa. The overall function of the mini project was achieved by utilizing software and hardware in order to complete the objective of using switches on the Basys board in order to control the speed and direction of the DC motor. The completed mini project [Figure 9] demonstrated the progress of utilizing code and hardware production in order to further achieve the objective.

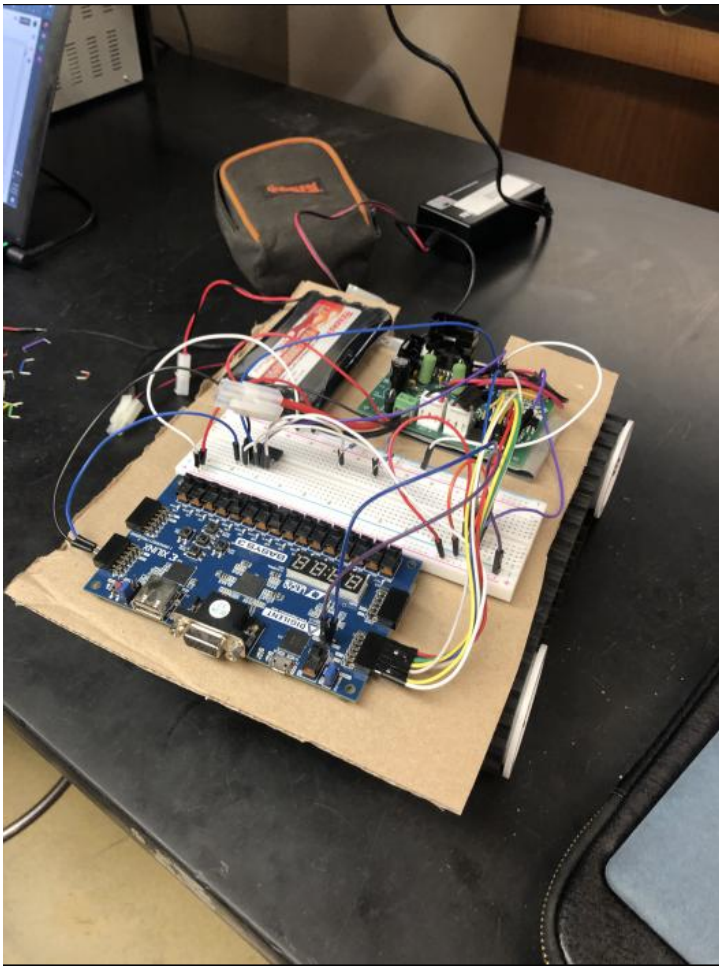


Figure 9: Completed Mini Project

References

1. *Basys 3 FPGA Board Reference Manual*. Diligent. (2016, April 8). Retrieved September 19, 2021, from https://digilent.com/reference/_media/basys3:basys3_rm.pdf.

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3. *How to use the L298N Dual H-Bridge Motor Driver*. Banana Robotics. (n.d.). Retrieved September 20, 2021, from https://www.bananarobotics.com/shop/How-to-use-the-L298N-Dual-H-Bridge-Motor-Driver.

4. Dahl, Ø. N. (2020, June 25). *What is an H-Bridge?* Build Electronic Circuits. Retrieved September 21, 2021, from https://www.build-electronic-circuits.com/h-bridge/.

Figures Reference:

Figure 2: *LM340/LM78XX Series 3-Terminal Positive Regulators*. DataSheet4U. (2006, July). Retrieved September 20, 2021, from https://datasheet4u.com/datasheet-pdf/NationalSemiconductor/LM340/pdf.php?id=49663

Figure 3: Dahl, Ø. N. (2020, June 25). *What is an H-Bridge?* Build Electronic Circuits. Retrieved September 21, 2021, from https://www.build-electronic-circuits.com/h-bridge/.

Figure 4: LM339 Reference Manual. Semiconductor Industries (2014, October) Retrieved September 20, 2021, from https://www.onsemi.com/products/signal-conditioning-control/amplifiers-comparators/comparators/lm339s.

Figure 5: Panhorst, J. (2021). *Hardware Circuit Schematic*. Retrieved September 20, 2021.

Figure 7: Panhorst, J. (2021). *Truth Table for Rover Speed and Direction*. Retrieved September 20, 2021.

Figure 8: Ramirez, J. (2021). *Verilog Coding: Pulse Width Modulation*. Retrieved September 20, 2021.

Appendix A

Budget

Project Lab 1	Current Totals			Estimated Total				Start Date	8/23/2021
Direct Labor	Hourly Rate	Hours	Total Pay	Hourly Rate	Hours	Total Pay		Today's Date	9/20/2021
James P.	15	55	$825.00	15	50	$750.00		End Date	9/20/2021
Josh R.	15	45	$675.00	15	50	$750.00			
Faithful K.	15	55	$825.00	15	50	$750.00			
Alex H.	15	55	$825.00	15	50	$825.00			
Jibin M.	15	55	$825.00	15	50	$750.00			
Labor Subtotal		Subtotal:	$2,325.00		Subtotal:	$3,825.00			
Labor Overhead	Rate:	50%	$1,162.50	Rate:	50%	$1,912.50			
Total Labor			$3,487.50			$5,737.50			
Contract Labor	Hourly Rate	Hours	Total Pay	Hourly Rate	Hours	Total Pay			
Lab Assistant	$40.00	3	$120.00	$40.00	5	$200.00			
Total Contract Labor			$120.00			$200.00			
Material Costs	Quantity	Value	Total Cost						
Breadboard	1	$5.00	$5.00						
LM339 Comparator	1	$0.50	$0.50						
5V Voltage Regulator	1	$0.75	$0.75						
Jumper Wire Pack	1	$2.00	$2.00						
13 K-Ohm Resistor	2	$0.13	$0.26						
1.3 K-Ohm Resistor	2	$0.49	$0.98						
Total Material Costs			$9.49						
Equipment Rental Costs	Value	Rental Rate	Rental Cost	Value	Rental Rate	Rental Cost			
Oscilloscope	$5,300.00	0.20%	$296.80	$5,300.00	0.20%	$296.80			
Rover 5	$60.00	0.20%	$3.36	$60.00	0.20%	$3.36			
Function Generator	$16.00	0.20%	$0.90	$16.00	0.20%	$0.90			
Multi-Meter	$149.00	0.20%	$8.34	$149.00	0.20%	$8.34			
Battery Pack	$17.00	0.20%	$0.95	$17.00	0.20%	$0.95			
Basys 3 Artix-7	$958.00	0.20%	$53.65	$958.00	0.20%	$53.65			
Power Supply	$1,700.00	0.20%	$95.20	$1,700.00	0.20%	$95.20			
Total Rental Costs			$459.20			$459.20			
Total Project Costs			$4,076.19			$6,406.19			

Appendix B

Gantt Chart

Mini Project								8/23/21	8/30/21	9/6/21	9/13/21	9/20/21
Task Name	Done	Josh	James	Faithful	Jibin	Alex	Location					
Lab Access												
Form Lab Group	100%	xx	xx	xx	xx	xx	Classroom					
Create Stockroom Account	100%	xx	xx	xx	xx	xx	Internet					
Lab Safety Quiz	100%	xx	xx	xx	xx	xx	Internet					
TTU Lab Safety Training Certification	100%	xx	xx	xx	xx	xx	Internet					
CPR training	100%	xx	xx	xx	xx	xx	Internet					
Sexual Harassment Prevention Training	0%						Internet					
Soldering Tutorial	100%	xx	xx	xx	xx	xx	Lab					
Obtaining a Bench	100%	xx	xx	xx	xx	xx	Lab					
Mini Project (Hardware)												
Reseach Circuit	100%	xx	xx	xx	xx	xx	Internet					
Obtain Necessary Components	100%	xx	xx	xx			Stockroom					
Construct Experimental Circuit	95%	xx	xx	xx	xx	xx	Lab					
Troubleshoot Circuit	95%		xx	xx	xx	xx	Lab					
Implementation of Overcurrent Protection	100%	xx	xx	xx	xx	xx	Lab					
Mini Project (Software)												
Research Code	100%	xx	xx	xx	xx	xx	Internet					
Write Code	100%	xx		xx			Lab					
Test Code	100%	xx	xx	xx	xx	xx	Lab					
PWM	100%	xx	xx	xx	xx	xx	Lab					
Seven-Segmement	90%	xx	xx	xx	xx	xx	Lab					
Overcurrent Protection	100%	xx	xx	xx	xx	xx	Lab					